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Final Report

# Edge-Joint Sealing as a Preventive Maintenance Practice



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# **EDGE-JOINT SEALING AS A PREVENTIVE MAINTENANCE PRACTICE**

## **Final Report**

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## **EXECUTIVE SUMMARY**

Preventive maintenance treatments such as joint sealing are part of ongoing research at the Minnesota Road Research test facility. Pavement sections at the test facility are instrumented extensively, thus providing automated measurements of changes in pavement moisture and drainage due to varying climate conditions. Joint sealing studies involve measuring changes in edge drain outflow and base moisture content in response to precipitation events. Concrete test sections and longitudinal edge drains were constructed. Data was collected before and after edge joints were sealed on concrete sections. There was no significant difference in the volume drained between the control and the test section prior to sealing the joint on the test section. After sealing the edge joint, there was a significant reduction in the volume drained from the test section. Sealing the edge joint on concrete pavements with bituminous shoulders is shown to reduce the total volume of water entering the pavement system by as much as 85% for a given rain event. Sealing the longitudinal edge joint on concrete pavements should be considered as a pavement preventive maintenance treatment.

## **INTRODUCTION**

Moisture entering the pavement system through joints and cracks contributes to loss of load bearing capacity and premature pavement failure. Pavement base and subgrade strength and stiffness depend on material moisture content. Therefore, reducing infiltration and removing excess moisture is critical to extend pavement life. Longitudinal joints in concrete pavement systems constructed with bituminous shoulders are known to be a weak part of the pavement-shoulder system (1). The longitudinal edge joint provides water direct access into the pavement system that can contribute to deterioration of the longitudinal joint. Deterioration of the edge joint compromises the structural integrity of both the pavement and shoulder. Cracking, spalling, faulting, and settling are associated with deterioration of the edge joint. There are resultant public safety issues to consider, as well.

Maintaining the longitudinal joint on concrete pavements can be costly. Preventive measures, consisting of relatively inexpensive joint sealing treatments, can reduce moisture infiltration into pavement systems.

## **BACKGROUND**

The Minnesota Department of Transportation (Mn/DOT) does not routinely seal the lane shoulder joint on concrete pavements with asphalt shoulders, primarily because it has been difficult to obtain a successful seal. Generally, there is a gradual deterioration of the asphalt shoulder adjacent to the pavement that leads to settling of the shoulder. A common maintenance practice is to “wedge pave” the settled shoulder with a fine aggregate asphaltic concrete mixture to eliminate the drop off at the pavement edge. In a study conducted at the Minnesota Road Research (Mn/ROAD) test site, it was noted that there was a significant reduction in water flow through the edge drains after a wedge pave treatment. These observations were the impetus for a study to measure the flow reduction when the lane shoulder joint was routed and sealed.

There are differing views on the benefits and cost-effectiveness of sealing edge joints on concrete pavements. In a previous Mn/DOT study, it was found that the volume of water drained through the edge drain returned to previously measured volumes shortly after the joint was sealed (2). Hagen and Cochran concluded that the benefits of sealing this joint are realized only in the very short term. If the sealant does not perform well over the long-term, joint deterioration will occur, and maintenance savings will not be realized.

Pavement preventive maintenance has been growing in popularity during recent years. Pavement preventive maintenance is a strategy of cost-effective surface treatments and operations performed to improve or extend the functional life of a pavement and reduce the development of pavement distress. As follow-ups to the Strategic Highway Research Program (SHRP), many maintenance strategies have been evaluated. One of the primary treatments that has been evaluated is the sealing/filling of joints to prevent the intrusion of water into the pavement system. Mn/DOT has been evaluating the performance and effectiveness of joint sealing for several decades. Recent improvements in joint sealing materials and methods require a return to the question of whether sealing the longitudinal joint can reduce moisture infiltration over the long-term, and be cost-effective if adopted as a preventive maintenance procedure.

During 1999 and 2000, maintenance activities were conducted to extend the pavement life of Mn/ROAD as would be done with any pavement facility. The Mn/ROAD test facility provided an opportunity to measure the actual infiltration of moisture before and after joint sealing in the concrete pavement structure.

## **OBJECTIVE**

The objective of this study was to evaluate the effect of sealing the longitudinal joint by examining data collected from two drained concrete pavement test sections, one with the edge-joint sealed and one with the edge-joint unsealed. A comparative statistical analysis was used to evaluate the effects of sealing the longitudinal joint. Analysis variables were precipitation (event intensity), traffic condition, drainage, joint condition (sealed, unsealed), and time (before and after sealing the joint).

## **MATERIALS AND METHODS**

The Mn/ROAD research site consists of 40 test sections, including both flexible and rigid pavements of varying structural designs. The test sections are divided between two road segments--the mainline and low-volume loop. The test sections lie parallel to Interstate 94 outside Otsego, Minnesota, with the mainline pavement sections carrying live interstate traffic and the low-volume test loop simulating conditions on rural roads.

### ***Concrete Test Sections***

Five of the mainline concrete test sections were constructed with edge drains. Two similar test sections were selected for this study. Each cell was 152 meters in length with lane widths of 3.66 meters. Both test sections consisted of 240 mm of Jointed Portland Concrete (JPC) over 102 mm of a drained Permeable Aggregate Stabilized Base (PASB), overlying 76 mm of dense graded Class 4 Special granular subbase (Figure 1).

### ***Seal Testing: IA-VAC***

Test sections consisted of random effective 15-foot joint spacing, sealed with silicone joint sealant. To test the sealant integrity, the Iowa Vacuum Joint Seal Tester (IA-VAC) device was used to test for leakage (Figure 2). The IA-VAC is an innovative vacuum joint sealant testing device that detects unseen leaks in joint seals (3). This is accomplished by spraying the joint and surrounding pavement surface with a soap/water solution, placing the chamber over the pavement surface, and applying a vacuum above the seal. Air bubbles indicate seal leakage. This device was used to test both the PCC joints and the pavement shoulder edge.



### ***Drainage: Tipping Buckets***

Outflow from edge drains was measured by automated tipping buckets. In 1995, tipping buckets (Figures 3 and 4) were installed on drained test sections at the Mn/ROAD test facility. Test sections were constructed with longitudinal edge drains terminating at the headwall of tipping bucket enclosures. Tipping buckets provide a means for quantifying the volume of water that flows through the edge drain in response to a rain event. Flow is directed through the edge drain into the tipping bucket, resulting in a magnetic switch closure that generates an electrical pulse. Each tip of the bucket, or pulse, represents a calibrated volume of water. Each tipping bucket is wired to a datalogger that is programmed to count the number of pulses read during a 15-minute period. The data is stored on Campbell Scientific CR10X dataloggers. Data was manually downloaded to a PC on a weekly basis.

### ***Precipitation: Weather Station***

Climatological data collected by a Campbell Scientific weather station, located at the Northwest end of the Mn/ROAD site, was used to determine rain event volume and intensity. The EPA has determined that in Minnesota the summer rainfall intensity, during an average storm, is 2.54 mm (5). Determining rain event intensity for the Mn/ROAD site was accomplished by [1] determining the event season, [2] generating frequency diagrams for the measurement seasons (1998-2000), and [3] designating LOW and HIGH intensity events based on EPA guidelines. Frequency diagrams were generated between April 1 and November 1 for the years 1998 and 1999, and April -June 2000. These time periods simplified data analysis and eliminated periods of outflow due to precipitation other than rain (Figure 5).

### ***Traffic Conditions***

The Mn/ROAD site is a "live" research site, and traffic travels on the mainline but is periodically diverted to an adjacent roadway during designated sensor testing periods. Long-term drainage data collected at the Mn/ROAD test facility indicates that the volume drained is different when the traffic is running on the mainline than when it is off. The traffic variables "ON" and "OFF" were specified for analysis purposes.

## **MAINTENANCE PROCEDURES**

### ***Edge Joint Sealing Procedure***

Sealing the edge joint on the test section consisted of routing a 19 mm x 19 mm reservoir on the asphalt shoulder adjacent to the PCC edge (Figure 6). After clearing the reservoir of any debris, it was filled according to Mn/DOT specification 3725 with sealant. Crafcro 522 sealant was used in this study (Appendix A).

## **Data Analysis**

The effect of edge joint sealing on volume drained was determined as follows:

$$P_T = \text{Area} \times P_D \quad [1]$$

$$P_P = D_{Ta,b} / P_T \times 100 \quad [2]$$

$$\Delta D = (D_{Ta} - D_{Tb}) \times 100 \quad [3]$$

Where  $P_T$  is the total volume of precipitation fallen on the pavement section (liters),  $P_D$  is the precipitation depth (mm),  $P_P$  is the percent of the total volume drained, and  $\Delta D$  is the percent change in the volume drained for either the test section or the control section.  $D_{Tb}$  is the volume drained before the joint was sealed (liters);  $D_{Ta}$  is the volume drained after the joint was sealed (liters).

A paired t-test was used to perform a comparative analysis between the control and test sections for each experimental treatment. An analysis of variance (ANOVA) F test was used to compare treatments within the test section, and interactions between treatments such as event intensity and traffic conditions (4).

## **RESULTS AND DISCUSSION**

A plot of the frequency distributions for 1998-2000 (Figure 5) shows that the most frequent intensities for the Mn/ROAD site are in agreement with the 2.54 mm/hr average for this region. Although rarely were any events recorded at the Mn/ROAD site exactly 2.54 mm/hr., most of the events fell below or above the average. Therefore, intensities were designated as "Low" and "High" for analysis purposes.

Table 1 summarizes the percent change in the volume drained for single precipitation events before and after the edge joint was sealed. When comparing the  $D_{Tb}$  from the test and control sections, for a HIGH intensity event there was a 2% difference in the volume coming through the test joints. A comparison of the  $D_{Ta}$  between test and control sections showed an 89% reduction in outflow between the sealed and unsealed joints. Figure 7 illustrates the effect of sealing the joint. In the photograph, a distinct difference between the sealed and unsealed joint can be seen. The sealed test section is wet and water has ponded on the seal. The unsealed control section has allowed infiltration through the edge joint and is therefore dry. A comparison of  $D_{Tb}$  and  $D_{Ta}$  within the test sections shows an 86% reduction after the joint was sealed, with no change ( $\Delta D$  not significant) in outflow from the control section. Table 1 also summarizes the results of the joint sealing after the sealant had been through the 1999-2000 winter season. Two events are listed, one LOW and one HIGH intensity event. There was a 95% reduction in outflow between test sections for the LOW intensity event, and an 83% reduction in outflow for the HIGH intensity event. Within the test section there was a 76% reduction for the HIGH intensity event. These results are also confirmed by the IA-VAC tests performed on the longitudinal seals in the spring of 2000. Seal test results showed no leaks in the edge joint seal and minimal if any in the transverse seals.

Table 2 summarizes the results of the statistical analysis. Prior to sealing the joint on the test section, there is no significant difference in the volume drained between the control and the test sections, ( $\alpha=0.05$ ,  $p = 0.125$ ). After the edge joint was sealed there was a significant reduction in the volume drained through the edge drain on the test section, ( $\alpha=0.05$ ,  $p < 0.0001$ ). The results of the ANOVA show the reduction in the volume drained within the test section to be significant, with  $F = 28.315$ ,  $P > F$ ,  $<0.0001$ . The ANOVA also shows that there is no significant difference in event intensity when the traffic is "ON" the mainline. The implications of joint sealing as a preventive maintenance treatment are realized in reduced moisture infiltration and premature pavement deterioration, as well as reduced pavement maintenance costs.

The implications of this study extend beyond preventive maintenance practices. This study brings to the forefront the question of whether edge drains are providing positive drainage to the entire pavement system. In a previous Mn/DOT study (2), the volume drained is assumed to be equal to the total rainfall entering the pavement system. This study demonstrates that the assumption that edge drains are providing adequate positive drainage to the entire pavement system can be erroneous. The results of this study indicate most of the water draining through the edge drain is entering through the edge joint positioned directly above the drain pipe. It appears that the edge drain is not draining the pavement system but rather it is draining the edge joint. This is consistent with results from other edge drain studies (6). Birggison and Roberson (7) show that for a pavement of similar structural design, moisture infiltration through the edge joint can result in increased moisture content in the outer wheel path of the pavement base material. Data from the study indicates that the moisture content in the outer wheel path and the volume drained through the edge drain were reduced for a period of time after the shoulder was "wedge-paved", somewhat analogous to a seal. This suggests that increased moisture content in the base can be associated with infiltration into the pavement through the edge joint.

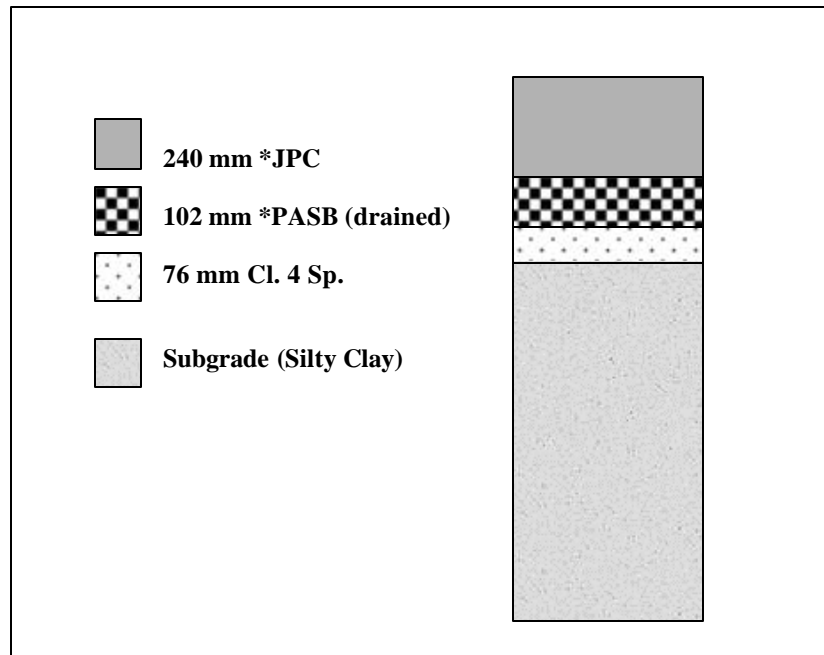
## CONCLUSIONS

Current joint sealing material and methods increase the potential for obtaining joint sealers that perform well over the long-term. Sealing longitudinal joints on concrete pavements with asphalt shoulders mitigates moisture infiltration into the pavement system. Sealing the edge joint reduces infiltration by hundreds to thousands of liters. Sealing the longitudinal edge joint on concrete pavements should be considered as a pavement preventive maintenance program.

The presence of edge drains does not ensure adequate positive drainage for the entire pavement system. Evaluating pavement drainage design and performance requires more than measuring outflow from edge drains. It requires an integration of pavement base and subbase material moisture properties, structural geometry, and climate factors.

## REFERENCES

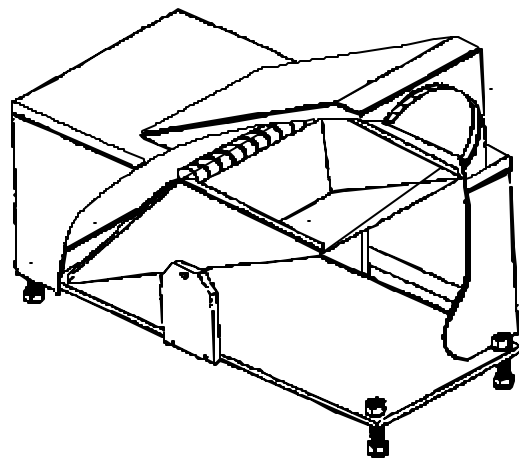
1. Barksdale, R. D. and R. G. Hicks. *Construction and Performance of Sealed Longitudinal Pavement-Shoulder Joints*. Presentation. Transportation Research Board, Washington, D.C., Jan. 1976.
2. Hagen, M. G. and G. R. Cochran. Comparison of Pavement Drainage Systems. *Transportation Research Record No. 1519*, Transportation Research Board, Washington, D.C., 1996, pages 1–10.
3. Steffes, R. F., Innovative Leak Test for Pavement Joint Seals. Presentation. Transportation Research Board, Washington, D.C., Jan. 1993
4. *JMP Manual*, version 3.1, SAS Institute Inc, Cary, NC
5. Spoden, Greg. E-mail to the author. 11 Jun. 2000.
6. Ahmed, Z., T. D. White, and T. Kuczek. Comparative Field Performance of Subdrainage Systems. *Journal of Irrigation and Drainage Engineering*, May/June 1997.
7. Birgisson, B. and R. Roberson. *Drainage of Pavement Base Material: Design and Construction Issues*. Accepted for publication, Transportation Research Board, Washington, D. C., 2000.
8. Johnson, A. M. *Best Practices Handbook on Asphalt Pavement Maintenance*, Minnesota Department of Transportation, St. Paul, Mn., 2000.



*Figure 1:* Drained concrete test section structural design. JPC = Jointed Portland Concrete, PASB = Permeable Asphalt Stabilized Base, CL. 4 Sp. is a Mn/ROAD Class 4 aggregate base material.



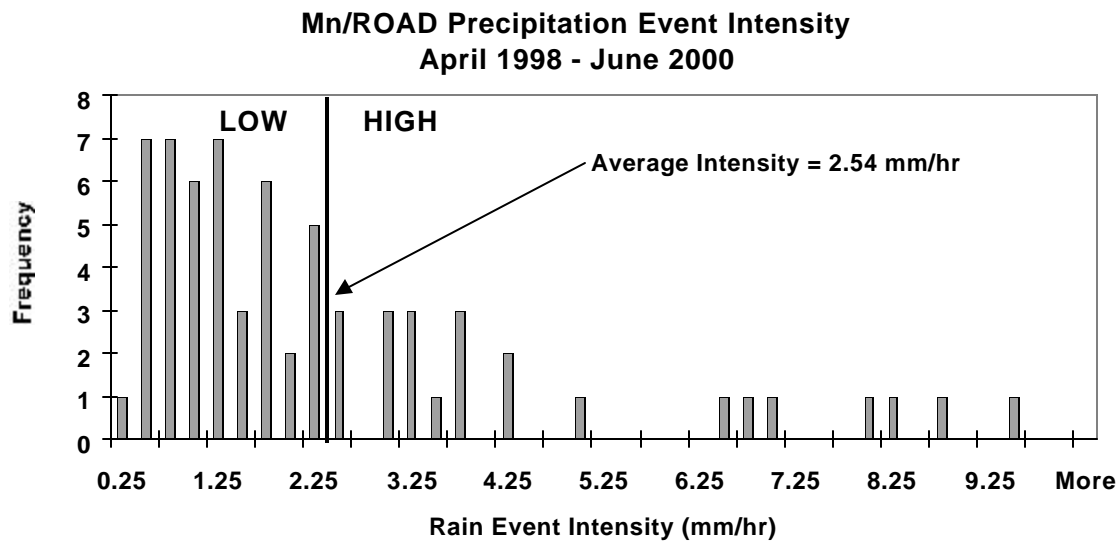
*Figure 2:* Seal testing on concrete test pavement using the IA-VAC device



*Figure 3: Low profile tipping bucket*



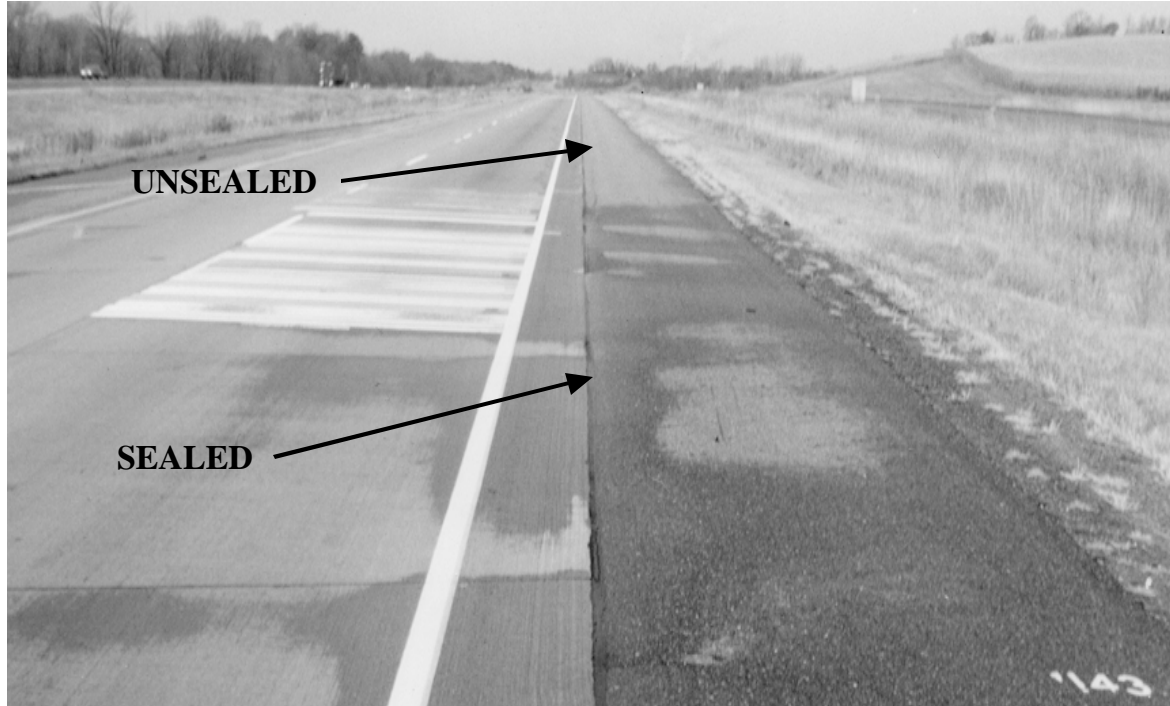
*Figure 4: Edge drain outlet and tipping bucket enclosure*



*Figure 5:* Frequency distribution of rain event intensity for the Mn/ROAD research site 1998-2000. Low < 2.54 mm/hr, High > 2.54 mm/hr.



*Figure 6:* Route and Seal according to Mn/DOT Specification



*Figure 7:* Concrete test sections after a rain event. Test section is sealed, control section is unsealed.



<b>BEFORE (1999)</b>						
EVENT INTENSITY (EPA STANDARD)	TRAFFIC	TOTAL VOLUME (liters),(P <sub>T</sub> )	TEST VOLUME DRAINED (liters),(D <sub>T</sub> )	CONTROL VOLUME DRAINED (liters),(D <sub>T</sub> )	REDUCTION BETWEEN SECTIONS (%), (ΔD <sub>T</sub> )	REDUCTION WITHIN TEST SECTION (%)
HIGH	ON	15858	2005	2223	<b>NONE</b>	<b>N/A</b>
<b>AFTER (joint sealed June 15, 1999)</b>						
HIGH	ON	11466	281	2607	<b>89</b>	<b>TEST=86 CTRL = NONE</b>
<b>AFTER 1999-2000 WINTER</b>						
LOW	ON	3400	73	1434	<b>95</b>	<b>N/A</b>
HIGH	ON	8355	482	2831	<b>83</b>	<b>TEST=76 CTRL = NONE</b>

*Table 1:* No difference in volume drained prior to sealing the test section. 89% reduction for the High intensity event between the test (sealed) and the control (unsealed) sections. Comparisons within the section show an 86% reduction in the test section, and no change in the control section. After the 1999-2000 winter season, the reduction in flow is 95% for a Low intensity event, and an 83% reduction for a High intensity event. Within the test section, comparing events of similar intensity from 1999 to 2000, there is a 76% reduction for a High intensity event. No change in the control section.

## Summary of Statistics

Mean Difference(liters)		t*-critical		p-value	
BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
202.8728	2253.459	1.675	7.062	0.125	< 0.0001
Analysis of Variance (ANOVA F test)		Prob > F		< 0.0001	

*Table 2:* Results of paired t-test show no significant difference in outflow volume between the control and the test sections,  $\alpha = 0.05$ , before edge joint sealing. After edge joint sealing there is significant difference, at  $\alpha = 0.05$ . The ANOVA shows reduction in the volume drained within the test section to be significant.

## APPENDIX A

### 3725 Joint and Crack Sealer (Hot-Poured, Extra Low Modulus, Elastic Type) December 1998

#### 3725.1 SCOPE

This specification covers joint and crack sealer of the hot-poured, extra low modulus, elastic type, for sealing joints and cracks in concrete and bituminous pavements, bridges, and other structures.

#### 3725.2 REQUIREMENTS

##### A General Requirements

The sealant shall be composed of a combination of polymeric materials, fully reacted chemically to form a homogeneous compound. Only material from certified sources is allowed for use. The sealant must be melted in a double boiler, oil jacketed melter-applicator equipped with a mechanical agitator, pump, gas pressure gauges, separate temperature thermometers for the oil bath and melted material with accessible control valves and gauges. Follow melting procedures recommended by supplier.

The sealant, when melted, shall be free of any dispersed or settling component and be of uniform consistency suitable for filling joints and cracks without inclusion of large air holes or discontinuities.

##### B Physical Requirements

The sealant shall conform to the following properties when heated in accordance with ASTM D5167:

- (1) Cone penetration, 77F, dmm (ASTM D5329) 100 - 150
- (2) Cone penetration, -0F, dmm (ASTM D5329 modified) 25 min.
- (3) Flow, 140F, 5h (ASTM D5329) 10 mm max.
- (4) Resilience (ASTM D5329) 30 - 60 %

- (5) Bond, -20F, 200% extension (ASTM D5329) Pass 3 cycles
- (6) Asphalt Compatibility (ASTM D5329) Pass

The sealant material may be subjected to any or all of the above tests after prolonged heating of the material for 6 hours with constant mixing in a laboratory melter at the manufacturer's recommended pouring temperature. After such heating, the material shall meet the above specified requirements.

#### C Packaging and Marking

The sealant material shall be packaged and shipped in suitable commercial boxes, of no more than 50 lb. weight, clearly marked with the name of the material, the name of the manufacturer, brand name, mass, batch number, and pouring temperature recommended by the manufacturer.

### 3725.3 SAMPLING AND TESTING

#### A Sampling

Samples shall be furnished for testing in such size and number as directed by the Engineer.

#### B Methods of Test

- B1 Testing shall be according to ASTM D5329 except the bond test will be run using sawed cement mortar blocks prepared by the Mn/DOT method.
- B2 Cement Mortar Blocks ( Mn/DOT Method). Prepare mortar using one part high early Portland Cement conforming to AASHTO M 85 Type III and two parts by weight of clean, uniformly graded, concrete fine aggregate conforming to AASHTO M 6. Add sufficient water to produce a flow of  $100 \pm 5$  when tested in accordance with the procedure for determination of consistency of cement described in section 9 of AASHTO T 106, Test for Compressive Strength of Hydraulic Cement Mortars (using 2 in. cube specimens). After curing one day in moist air and six days in water at  $74 \text{ F} \pm 3 \text{ F}$ , the blocks shall be cut into 1 by 2 by 3 inch test blocks using a diamond saw blade. Discard the one inch strips in contact with the vertical sides of the mold. Immerse the mortar blocks in lime saturated water for not less than two days prior to use. To prepare specimens, remove from lime water and scrub the block faces with a stiff bristle brush holding the block under running water. Blot the washed blocks with absorbent lint-free cloth or blotting paper. Allow the blocks to air-dry for one hour before assembling and filling. Assemble the blocks  $0.50 \pm 0.10$  inch apart enclosing a reservoir of 2 by 2 by 0.50 inch.